Identification and Control of a Laboratory Distillation Column

Martin Klaučo
Martin Jelemenský, Richard Valo, Miroslav Fikar

Slovak University of Technology in Bratislava, Slovakia

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STU FCHPT

Distillation

- Separation process based on different volatility of substances
- Mixture of methanol and water
- Obtain distillate of given concentration
- Temperature control

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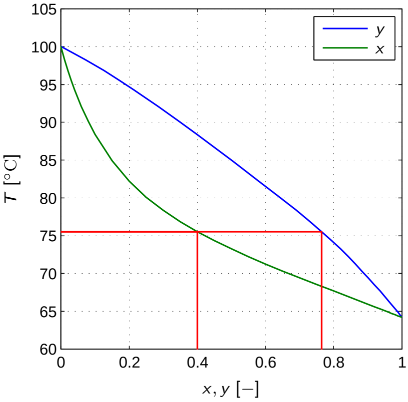
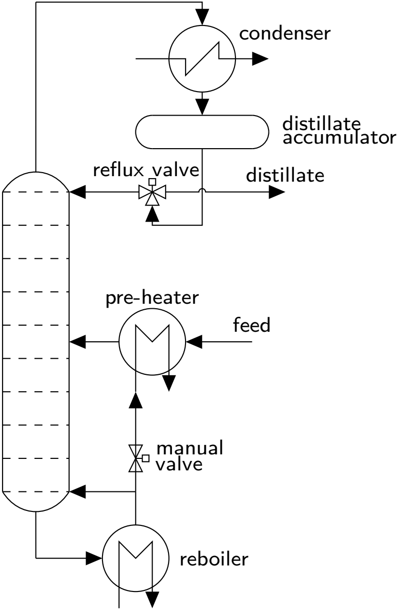
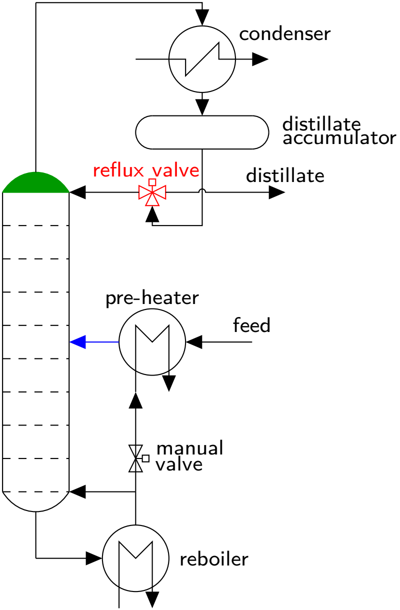


Distillation Column



Distillation Column



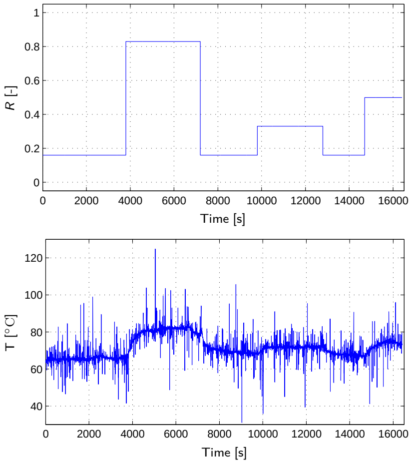
- **PV:** Temperature
- **MV:** Reflux ratio
- **DV:** feed temperature

Control Design

- Identification
- State estimator design
- Model Predictive Controller design
- Controller and estimator tuning

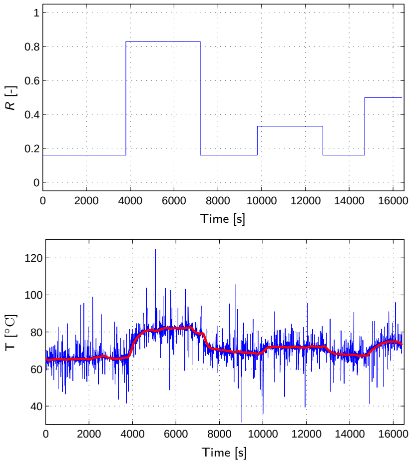
Identification

- Perform step responses



Identification

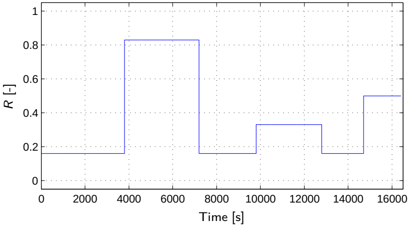
- Perform step responses
- Butterworth low pass filter ($\omega_n = 0.005\text{rad/s}$)

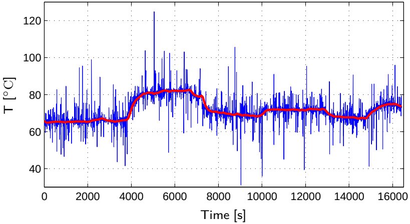


Identification

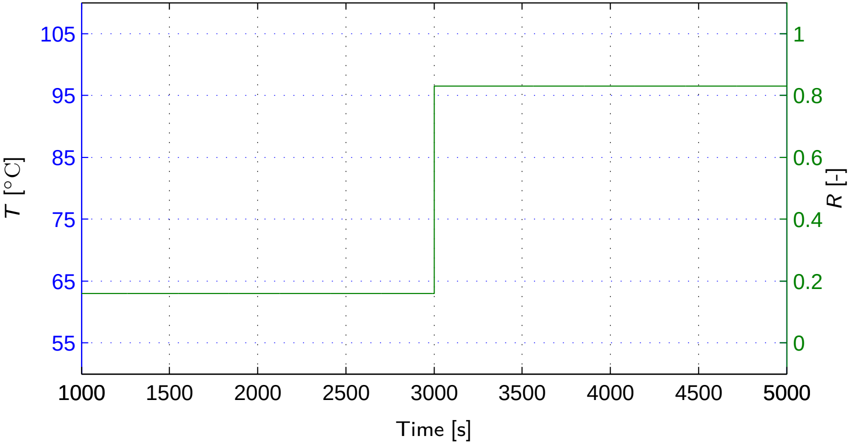
- Perform step responses
- Butterworth low pass filter ($\omega_n = 0.005$rad/s)
- MATLAB identification toolbox

$$x_{k+1} = Ax_k + B(u_k - u^s)$$
$$y = Cx_k + y^s$$

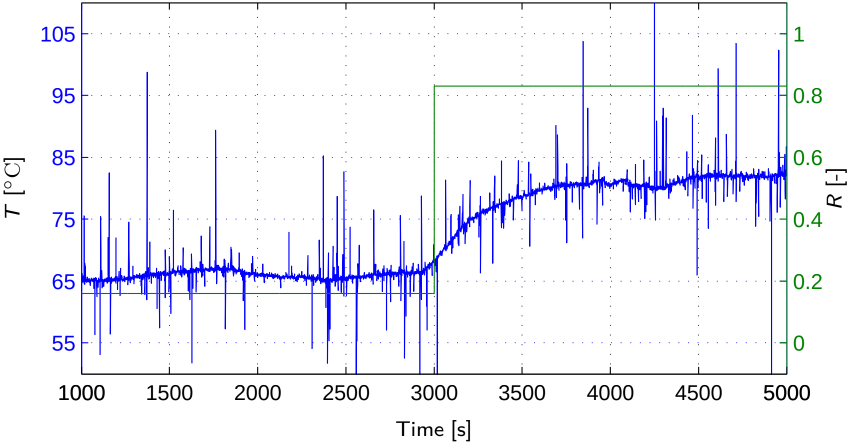




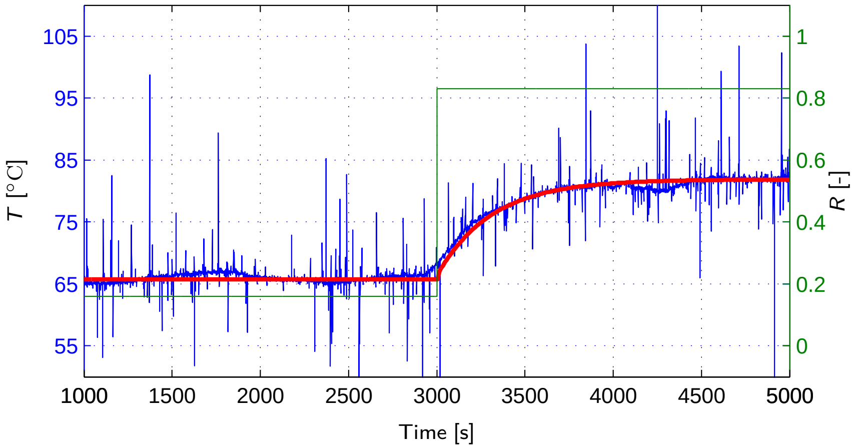
Model Validation



Model Validation



Model Validation



State Estimator and Disturbance Modelling

Stationary Kalman filter:

$$\begin{bmatrix} \hat{x} \\ \hat{d} \end{bmatrix}_{k|k} = \begin{bmatrix} \hat{x} \\ \hat{d} \end{bmatrix}_{k|k-1} + L\left(y_{m,k} - \hat{y}_{k|k-1}\right)$$

$$\begin{bmatrix} \hat{x} \\ \hat{d} \end{bmatrix}_{k|k+1} = \begin{bmatrix} A & E \\ 0 & I \end{bmatrix} \begin{bmatrix} \hat{x} \\ \hat{d} \end{bmatrix}_{k|k} + \begin{bmatrix} B \\ 0 \end{bmatrix} u_{k|k}$$

$$\hat{y}_{k|k} = \begin{bmatrix} C & F \end{bmatrix} \begin{bmatrix} \hat{x} \\ \hat{d} \end{bmatrix}_{k|k} + Du_{k|k}$$

Model Predictive Control

$$\min \quad \sum_{k=1}^{N} ||r_k - \hat{y}_k||_Q^2 + \sum_{k=1}^{N} ||\Delta u_k||_S^2$$

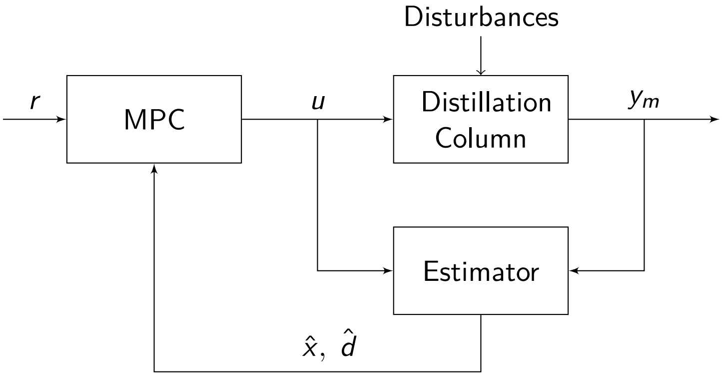
Model Predictive Control

$$\begin{aligned} \min \quad & \sum_{k=1}^{N} ||r_k - \hat{y}_k||_Q^2 + \sum_{k=1}^{N} ||\Delta u_k||_S^2 \\ \text{s.t.} \quad & \hat{x}_{k+1} = A\hat{x}_k + Bu_k + E\hat{d}_k \\ & \hat{y}_k = C\hat{x}_k + Du_k + F\hat{d}_k \end{aligned}$$

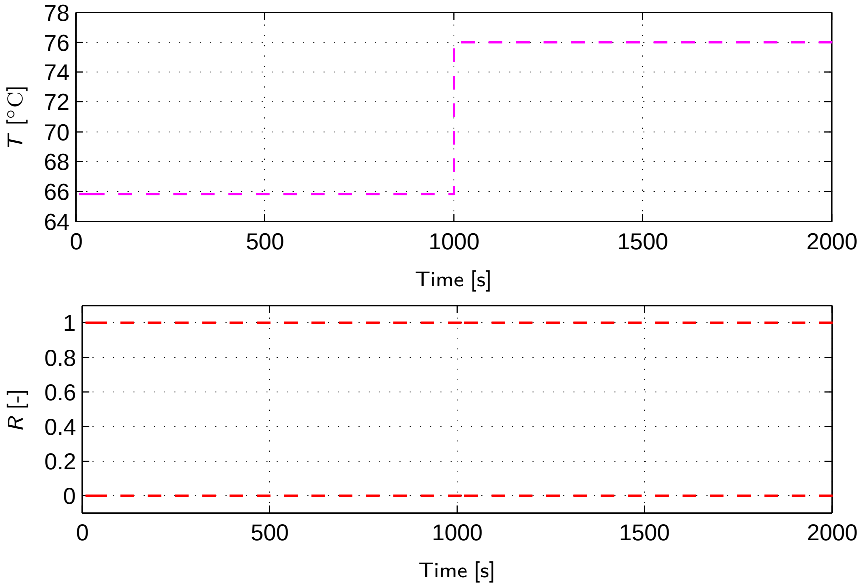
Model Predictive Control

$$
\begin{aligned}
\min \quad & \sum_{k=1}^{N} ||r_k - \hat{y}_k||_Q^2 + \sum_{k=1}^{N} ||\Delta u_k||_S^2 \\
\text{s.t.} \quad & \hat{x}_{k+1} = A\hat{x}_k + Bu_k + E\hat{d}_k \\
& \hat{y}_k = C\hat{x}_k + Du_k + F\hat{d}_k \\
& u_{\min} \leq u_k \leq u_{\max}
\end{aligned}
$$

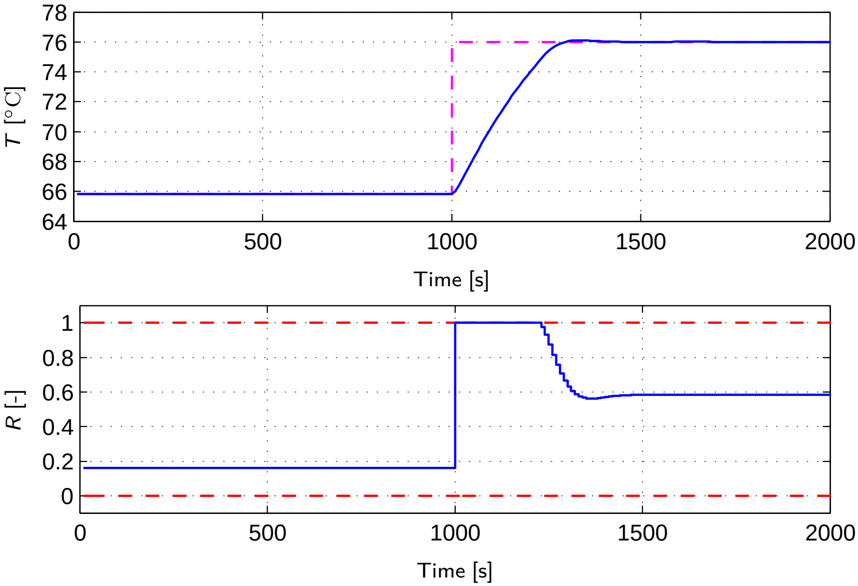
Scheme of MPC Closed Loop



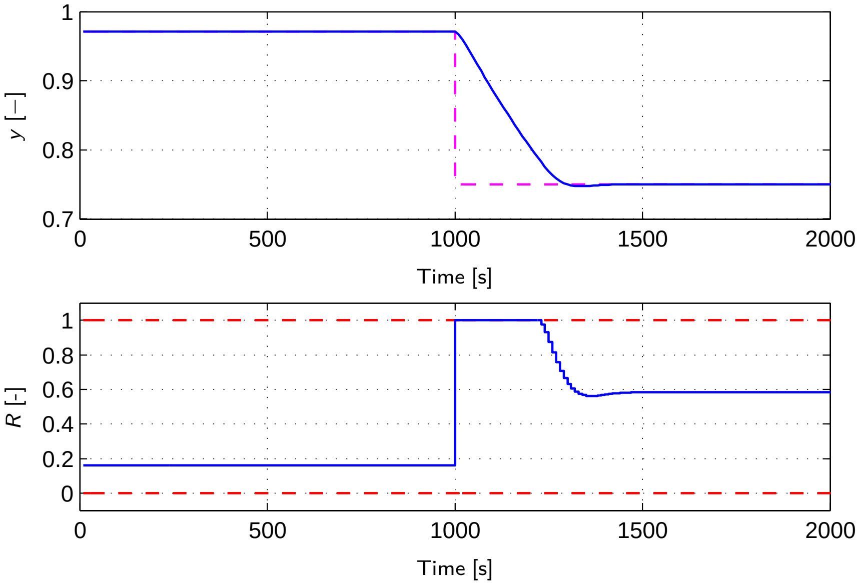
Simulation Results



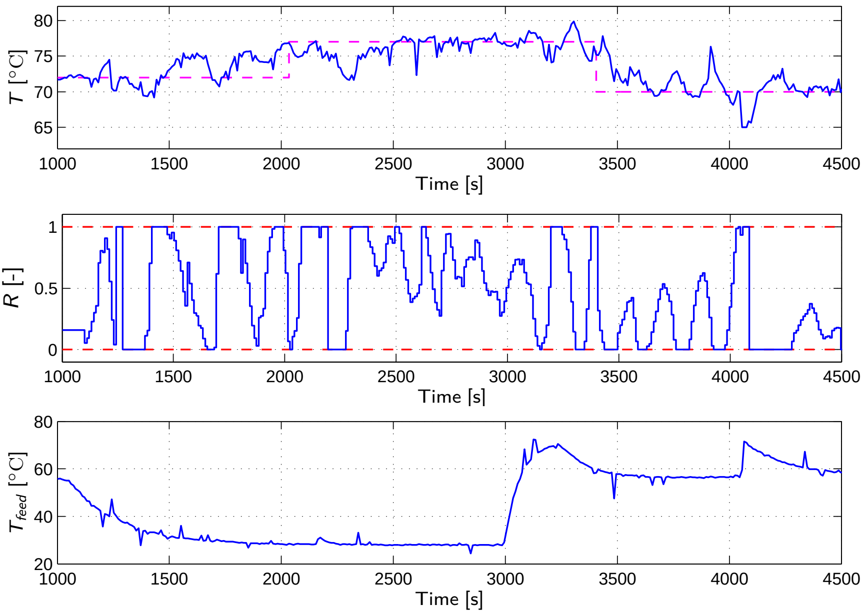
Simulation Results - Temperature Profile



Simulation Results - Concentration Profile



Experimental Results



Conclusions

What has been done:

- Identification of laboratory distillation column
- Implementation of MPC based on state space model

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What has been done:

- Identification of laboratory distillation column
- Implementation of MPC based on state space model

What is being done:

- Tuning of MPC and estimators for controlling laboratory device